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The Role of Simulation in a Cyber-Physical Production Environment

Simulation in einem Cyber-physischen Produktionssystem

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Abstract: This article introduces the establishing of digital twins for cyber-physical production systems. A interactive live connection (OPC-UA) using industrial PLC network and a discrete event simulation tool is made between physical and cyber world. Based on this achievement a digital twin based simulation framework method will be presented.

1 Introduction

In recent years Industry 4.0 has played an increasing role within production environments. It is based on cyber-physical systems (CPS), where the physical and cyber (virtual) elements are in close interaction with each other. In such environments, the data collection and analysis is carried out in a network structure. In production environments, cyber-physical production systems (CPPS) are evolving. This progress is based on three main science fields: computer science (CS), info-communication technologies (ICT) and manufacturing science technologies (Monostori 2016, Negri 2017). CPPS are horizontally and vertically integrated environments, where the planning processes of products, technology, production and logistical system are digitally interconnected and permeable (Schleich 2017). One of the main features of cyber-physical production systems is the Digital Twin model. These virtual models are mirroring the real world into the cyber space with the appropriate level of detail (Pfeiffer 2017, Schleich 2017). Through the digitalisation of production, the digital twins can have a live connection to the real world, bringing their physical state changes directly into the virtual world. This enables a reactive or proactive planning using simulation as well (Enke 2018, Uhlemann 2017).

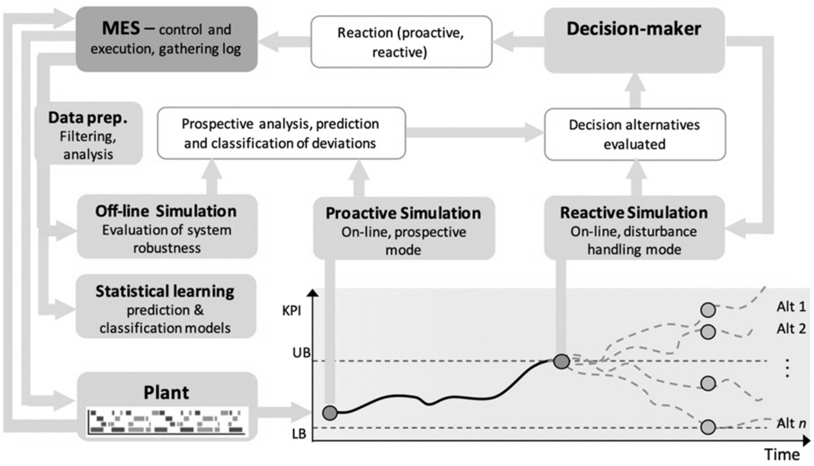

Figure 1: *Proactive planning and prescriptive simulation*

In Figure 1 the plant represents the underlying production system, which is generally controlled through an MES. Thus, lighter arrows represent production-related data provided by the plant (e.g., resource status, job completion, or, the performance measure of interest KPI in the current case), either gathered by the MES and stored as log data, or monitored on-line by, i.g. the simulation framework. Contrary, grey arrows represent an interaction or information exchange, e.g., the decision-maker might control the process of the production (highlighted as reaction) of the plant by the MES system.

In a real-world application, three main distinct operation modes follow each other during operation.

- Off-line validation, sensitivity analysis and statistical modelling of the system. Evaluation of the robustness of the system against uncertainties (e.g., different control settings, thresholds and system load levels). Consequently, this scenario analysis might point out the resources or settings, which can endanger the normal operation conditions. In Figure 1 Off-line simulation represents the comprehensive model of the plant.
- On-line, anticipatory recognition of deviations from the planned operation conditions by running the simulation parallel to the plant activities; and by using a look ahead function, support of situation recognition (proactive operation mode, Fig. 1).
- On-line analysis of the possible actions and minimisation of the losses after a disturbance already occurred (reactive operation mode, Fig.1), e.g., what-if scenario analysis.

The purpose of this work is introduced in our demonstration laboratory and present a possible method to use a Digital Twin to support the decision-making processes.

2 Industry 4.0 Laboratory at SZE

The laboratory of the Department of Automobile Production Technologies at the Széchenyi István University has a FESTO didactic system with modular elements, a FANUC manufacturing cell with two robots and three workplaces with collaborative UR robots (Fig. 2). Siemens S7-300 PLCs control the modular FESTO didactic line components of this system. These are linked through a switch and then a main central control is delivered by a Siemens S7-1500. A second Siemens S7-1500 carries out the operations of the FANUC cell, the PLC uses a Profibus protocol to communicate with the robots.

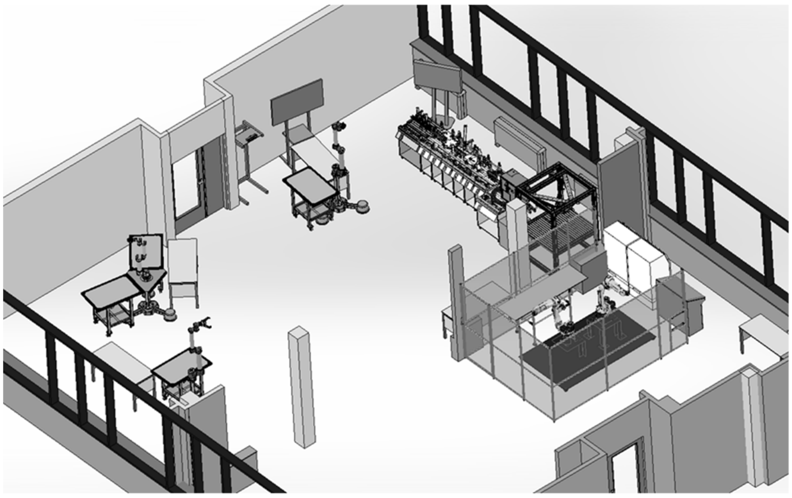

Figure 2: *3D model of the laboratory*

2.1 Cyber System

In this stage of the development, Siemens Plant Simulation is the environment used for modelling the real system. This discrete event-driven simulation (DES) tool provides an appropriate environment for mapping events of PLCs and robot controllers. CAD models created based on the real system have been integrated into this environment. There is an opportunity to use 3D models and animations, but the detailed preparation of these animations are not complete yet. As shown in Figure 3, the tracing of the product, the material flow is modelled at the animation level. However, information on all processes in the real system is available in this digital system.

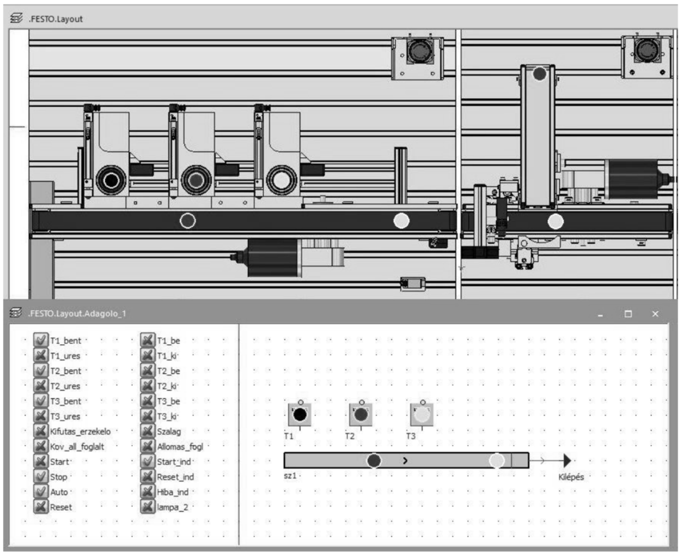

Figure 3: *Digital system, Plant Simulation model*

2.2 Communication System

The applied discrete event simulation tool and the physical system are connected to each other through an industrial communication interface called OPC-UA (Fig.4).

In the process of selecting the communication system, the primary aspect was that data exchange could take place in the most direct way possible, so a protocol had to be found that was supported by the system's components originally. At the same time, the programmability of the communication protocol information model was an important aspect, as different data from different units in the laboratory might be required. This technology widely supported by different brand of PLCs, robots and other industrial appliances and software solutions.

The OPC-UA is a machine-to-machine (M2M) communication protocol for Industry 4.0 systems. This protocol is an open standardised software interface on highest communication levels in production. OPC-UA is applied in several different fields such as automation, manufacturing simulation, process control and others. OPC-UA offers an opportunity to structure and describe system and plant components using an information model (Mahnke 2009, Zezulka 2018).

The main advantages of OPC-UA are:

- platform-independence,
- robust security,
- server oriented architecture (SOA),
- scalability,
- redundancy,
- can be structured,

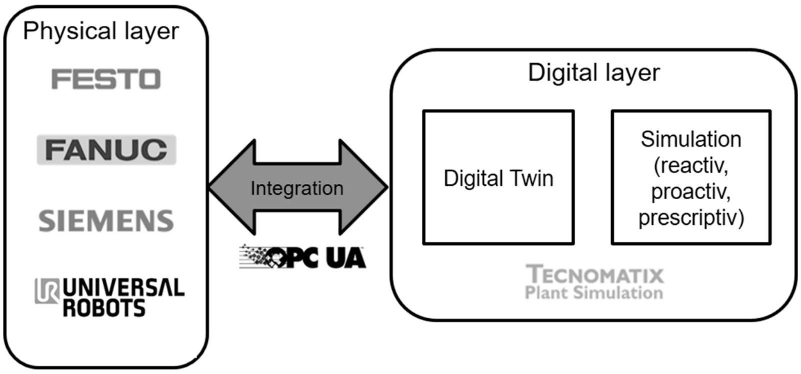

Figure 4: *Communication model*

3 Conceptual Digital Twin-based Simulation Framework

In this article, the usability of the digital twin is analysed. As the Figure 1 shows, collecting and analysing data from the system under review is a key part of the simulation framework. One of the basic pillars of Industry 4.0 is data collection and analysis. Thus, the purpose of this kind of supplement to the framework was to connect to and develop with tools that respond to the trend of the fourth industrial revolution.

The physical system itself carries a huge amount of data sources. Selection of relevant data and its collection in the right form is a very complex and complicated task. In most cases, PLCs and robot controllers that are programmed to perform the specified task under a specified set of conditions provide the automation control function. Data collection on these field devices has several disadvantages. One drawback is that it is necessary to know what data has to be collected and how it should be collected during the programming phase. Therefore, it may be easy to intervene in several parts of the program structure if a change is needed in the data collection. The design of these devices results in another major disadvantage, which is the scarce storage and computing capacity. Both of these drawbacks can be eliminated as soon as we connect the system's physical and cyber layers. As a result of CPS, all information about events in the real system is received in the simulation environment. Collecting information in this form is simpler and faster, as there is much more storage and computing capacity available, and this kind of solution is able to create more complex data logic.

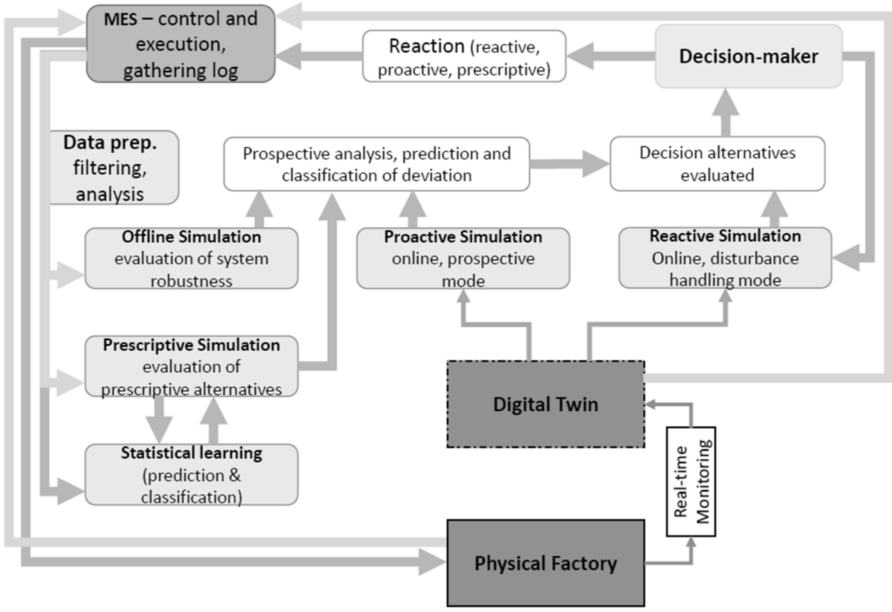

Figure 5: *Digital Twin -based conceptual simulation framework*

As shown in Figure 5, the source of data collection in the extended framework is a digital twin that is already in real-time contact with the physical factory. The data generated here is the input and descriptive data needed for simulations for different purposes. The results of these simulations help to make a decision, which may result in automatic or human intervention depending on the kind of decision and the available conditions. Since the data required for the various interventions may not be available at all and there may be decision-making situations for which the decision-making system was not prepared due to the complexity of the production structure, the work of the interveners may also be assisted. The decision-maker can access all the information about the current state of the system along with log and other data. In addition, data that are logged by the DT simulation model allows playback. During playback, errors or disturbances that were previously present but are not there anymore can be explored and analysed. With this, the method can be used not only to support decision-making but also to continuously improve processes.

4 Summary

The simulation-based predictive framework introduced in Figure 1 can be extended with the functionality of Digital Twin (Fig. 5). The live and interactive connection between the physical and digital counterparts enables data gathering, analysing and system configuration. The framework makes it easier to retrieve data because it is not extracted from the real system but from a more easily accessible digital twin. In a real industrial environment, this saves time and money without having to shut down the production system to supplement the PLC or robotic program with additional data acquisition logic. In addition, the digital twin makes it faster to connect different IoT and other IT systems, and to share information from other members in the supply chain that can influence manufacturing and logistics tasks. Based on more and more accuracy e of the collected data, on statistical learning and on the ability to simulate different scenarios, prescriptive alternatives can be evaluated. The results could serve as basis for the decision making processes.

The next step of the research is the measurement and quantification of the results achieved so far.

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